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Wetzel, Heike; Growitsch, Christian

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Economies of Scope in European Railways: An Efficiency Analysis

Heike Wetzel, University of Lueneburg
Christian Growitsch, IWH Halle

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Heike Wetzel, University of Lueneburg
Christian Growitsch, IWH Halle

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Autoren: Christian Growitsch

Halle Institute for Economic Research
E-Mail: christian.growitsch@iwh-halle.de
Tel.: ++49 345 77 53 864

Heike Wetzel

University of Lueneburg
E-Mail: wetzel@uni-lueneburg.de
Tel. ++49 4131 6772324

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INSTITUT FÜR WIRTSCHAFTSFORSCHUNG HALLE – IWH
Prof. Dr. Ulrich Blum (Präsident), Dr. Hubert Gabrisch (Forschungsdirektor)
Das IWH ist Mitglied der Leibniz-Gemeinschaft

Hausanschrift: Kleine Märkerstraße 8, 06108 Halle (Saale)
Postanschrift: Postfach 11 03 61, 06017 Halle (Saale)
Telefon: (0345) 77 53-60
Telefax: (0345) 77 53-8 20
Internetadresse: http://www.iwh-halle.de

Economies of Scope in European Railways: An Efficiency Analysis

Abstract

In the course of railway reforms in the end of the last century, national European governments, as well the EU Commission, decided to open markets and to separate railway networks from train operations. Vertically integrated railway companies – companies owning a network and providing transport services – argue that such a separation of infrastructure and operations would diminish the advantages of vertical integration and would therefore not be suitable to raise economic welfare. In this paper, we conduct a pan-European analysis to investigate the performance of European railways with a particular focus on economies of vertical integration. We test the hypothesis that integrated railways realise economies of joint production and, thus, produce railway services on a higher level of efficiency. To determine whether joint or separate production is more efficient we apply a Data Envelopment Analysis super-efficiency bootstrapping model which relates the efficiency for integrated production to a virtual reference set consisting of the separated production technology. Our findings are that in a majority of European Railway companies exist economies of scope.

Keywords: Efficiency, Vertical Integration, Railway Industry

JEL-Classification: L22, L43, L92

Zusammenfassung

Im Zuge der Reformen der europäischen Eisenbahnindustrie entschieden die nationalen Regierungen Europas sowie die EU Kommission, die Eisenbahnmärkte zu liberalisieren und die Schieneninfrastruktur vom Fahrbetrieb organisatorisch zu trennen. Vertikal integrierte Eisenbahnunternehmen – Unternehmen, die sowohl das Schienennetz als auch den Transportbetrieb unterhalten – äußern die Befürchtung, daß eine solche Separierung Vorteile der vertikalen Integration (sogenannte Verbundvorteile) vermindern würde und somit nicht geeignet sei, die gesamtgesellschaftliche Wohlfahrt zu erhöhen. In diesem Aufsatz untersuchen wir mittels einer pan-europäischen Analyse die Produktivität europäischer Eisenbahnunternehmen und berücksichtigen dabei insbesondere etwaige Verbundvorteile indem wir überprüfen, ob integrierte Eisenbahnunternehmen eine höhere technische Effizienz aufweisen als vertikal separierte Unternehmen. Dazu berechnen wir ein Data Envelopment Analysis super-efficiency bootstrapping Modell, das die Effizienz der integrierten Produktionstechnologie im Verhältnis zu einer Referenzgruppe virtueller, aus den separierten Unternehmen konstruierter Beobachtungseinheiten berechnet. Unsere Forschungsergebnisse weisen auf existierende Verbundvorteile für die Mehrzahl der europäischen Eisenbahnunternehmen hin.

Stichworte: Effizienz, Verbundvorteile, Eisenbahnindustrie

1 Introduction

In the late eighties and early nineties of the last century, national European governments, as well the EU Commission, decided to introduce competitive elements into the railway sector. The railway sector had been seen as performing poorly due to high subsidy requirements and an increasingly falling market share compared to other modes of transportation. The predominant means of restructuring industry had been the opening of markets and the separation of infrastructure from operations (Nash and Rivera, 2004). However, in many European countries vertical integrated firms still own the railway infrastructure and even participate on the transport segment. Although they are obliged to grant access to the infrastructure to third parties and to organisationally separate the infrastructure and transportation business, there is still a potential for market foreclosure. An expanded institutional unbundling in the means of complete ownership separation could eliminate this problem. Some European countries, like the United Kingdom and Sweden, already implemented new institutional arrangements: in the particular countries a state-controlled firm owns the infrastructure and provides network access and services to numerous competitive transportation firms. In other countries, such as Germany or Austria, the railway sector is still dominated by integrated incumbents. These firms argue that an institutional separation would diminish the advantages of vertical integration and would therefore not be suitable to raise economic welfare. Such *economies of scope* could result either from technical advantages or transactional advantages of joint production. If these would be in existence then an integrated market structure would be efficient; if not, a separation with competition in transport operations would be advantageous.

Following this argumentation a decision in favour or against institutional separation necessitates an analysis concerning potential economies of scope within the railway sector. Previous research (for instance Bitzan, 2003 or Ivaldi and McCullough, 2004) addressed this issue without actually comparing different production technologies and was based on a single country level only. In this paper, we conduct a cross-country analysis to investigate the performance of European railways with particular focus on economies of scope. Our sample consists of about 50 railway companies from 27 European countries, observed over a period of five years from 2000 to 2004. The companies represent a variety of different firm sizes, input-output combinations and, most importantly, different institutional settings, namely vertically integrated railways and unbundled network and train operators. To test the hypothesis that integrated railways – companies owning a network and providing transport services – realise vertical and/or horizontal economies of scope, we analyse if integrated companies are relatively more technically efficient compared to unbundled railways by applying a distance function model. In contrast to previous research, this allows us to refrain from determining the firms' maximisation

concern, which is crucial for a sample of regulated companies.[1] Our analysis adopts a two step approach. In the first step we estimate technical efficiency of integrated and non-integrated railways using data envelopment analysis (DEA). In order to make a set of non-integrated railways comparable to the integrated railways we follow a suggestion by Morita (2002) and construct virtually integrated firms from samples of different unbundled firms. Subsequently, in the second step, we determine whether joint or separate production is more efficient. Therefore, we apply a DEA super-efficiency model, which relates the efficiency for the integrated production to a reference set consisting of the separate production technology.

This paper aims to fill the void in previous research and empirically analyses on the question of whether economies of scope in railways exist or not. For that purpose, we calculate the relative efficiency of integrated railways compared to separated network and railway service operators. The outline for the remainder of this paper is as follows. The theoretical foundations and previous literature are presented in Section 2. Section 3 discusses methodology. In Section 4 we introduce the modelling approach and describe the data. Estimation results are presented in Section 5. Section 6 contains conclusions and highlights policy implications and directions for future research.

1 For discussion of distance functions in favour of cost or revenue functions, see *Coelli and Perelman* (2000) and section three of this paper.

2 Efficiency and economies of scope

The main argument against vertical and horizontal separation (or the unbundling of services respectively) in the railway industry has been the potential existence of significant economies of scope. However, empirical evidence for scope economies in railways is scarce. This section provides a theoretical overview on the conditions of economies of scope and their possible sources in railway industries. We then review previous research on efficiency and scope economies in railways and present the ability of non-parametric frontier techniques measuring economies of scope.

Economies of scope arise, in general, when cost savings can be realised due to a joint production of goods. Hence, it is more efficient to produce a certain output vector by a single firm than separately in two or more firms. Technically, economies of scope occur when the costs of producing the output vector Y_i, i= 1,…,m, jointly are lower than the costs of producing the same output vector separately (Baumol, Panzar and Willig, 1982):

$$C\left(\sum_{i=1}^{m} Y_i\right) < \sum_{i=1}^{m} C(Y_i) \tag{1}$$

Diseconomies of scope occur when that inequality is reversed. For the case of railway production, the output vector may be divided into infrastructure management (Y_I), passenger transportation (Y_P) and freight transportation (Y_F). Vertical and/or horizontal economies of scope exist when the inequality

$$C\left(Y_I, Y_P, Y_F\right) < \begin{cases} C\left(Y_I\right) + C\left(Y_P\right) + C\left(Y_F\right) \\ C\left(Y_I + Y_P\right) + C\left(Y_F\right) \\ C\left(Y_I + Y_F\right) + C\left(Y_P\right) \\ C\left(Y_I\right) + C\left(Y_F + Y_P\right) \end{cases} \tag{2}$$

holds: any linear combination of outputs - apart from complete joint production itself - comes at higher cost than joint production. If this applies to railway production an integrated market solution with only one firm is favourable to a separated institutional arrangement, where the infrastructure manager is institutionally separated from passenger and freight operators.

The main argument in favour of economies of scope in the railway industry is that of potential transaction costs savings within an integrated organisation: Railway services are characterised by a high level of technological and transactional interdependence between infrastructure and operations. This includes long-term capacity allocation, security management, timetable coordination and investment planning as well as every day operational decisions on traffic coordination like train length, train speed or emergency

service. Technologically, all these activities can be organised within a hierarchical (integrated) structure as well as within a contractual market structure among separated firms. Depending on the amount of transaction costs either one has to be preferred.[2]

Supporters of an integrated structure argue for an increase in costs in a separated structure as with a rise in the numbers of operators the number of contract negotiations as well as technical and organisational interfaces will rise. While for real-time traffic coordination this argument does most likely not hold it may be a consideration in efficient long term allocation: real time traffic coordination costs do not depend on the number of operators on the network but on the number of the train movements. As long as only one network firm – either integrated or separated – is responsible for this production stage no significant transaction cost differences should be expected (Knieps, 2004). In opposition to this, identifying the efficient institutional arrangement for long term capacity allocation is rather sophisticated. Especially long-term investment decisions may differ among one integrated and several separated firms. Any decision, on either operations or infrastructure investment, needs comprehensive information about other parts of the system. For example, a passenger operator investing in high speed trains has to be sure that the track system is capable to provide high speed transportation. On the other hand, the infrastructure provider has to know what kind of capacity at what time and at what place is needed. Such coordination is information intensive. Whether this interaction can be provided at lower transaction costs within an integrated or separated structure cannot be identified easily. On a first glance, the number of participating firms in a separated system gives reason to assume the integrated system being favourable. Moreover, the flow of information in a widely branched inter-firm structure also bears huge risks of increasing information and hence transaction costs.

In relation to this another problem of long-term capacity allocation arises due to different investment incentives within the two possible institutional arrangements. For example, an integrated infrastructure provider and transport operator has an incentive to invest in network infrastructure in order to prevent his rolling stock from wear and tear. In a separated system, with other firms owning the rolling stock, this incentive disappears (Mulder et al., 2005). Analogous, a separated transport operator has no incentive to invest into his rolling stock to reduce the wear and tear of the tracks only. Hence, within a separated system the coordination of long term investment determines more (cost intensive) interactions and negotiations between the production stages. However, within an integrated organisation the lack of competition and the direct monetary connection between performance and counter-performance may result in an inefficient – also cost intensive – resource allocation. The question of which effect is being dominant remains hard to answer. Recapitulating, the discussion above shows how complex the interdependencies between infrastructure and operations are and hence how difficult the task of judging for or against economies of scope is. Thus, the optimal institutional arrangement in the railway sector becomes an empirical question.

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2 For a detailed description of transaction costs theory see *Williamson* 1975 and 1985.

Studies with specific focus on vertical separation and economies of scope are rather few. In a paper from 2003 Bitzan uses a data set of 30 US Class I freight railways covering the years 1983-97 to evaluate the cost implications of competition in the US rail freight industry. The results obtained by estimating a translog quasi-cost function indicate economies of vertical integration, suggesting that vertical separation leads to increased costs. However, considering different technological characteristics in other countries Bitzan restricts his findings to the US freight railway industry. Especially the European railway systems with usually much smaller networks and a high passenger fraction within the combined passenger and freight operations may lead to other cost implications of competition and/or separation from his point of view. Ivaldi and McCullough (2004) use a comparable data set of 22 US Class I freight railways covering the years 1978-2001. They evaluate the technological feasibility of separating vertically integrated firms into an infrastructure company and competing operating firms. The results obtained by estimating a generalized McFadden cost function indicate vertical as well as horizontal economies of scope in a technological sense. The authors state that vertical separation may lead to a 20-40 percent cost disadvantage over a vertically integrated system and to even greater disadvantages if bulk and general freight operations are separated likewise. Nevertheless, since observing integrated firms in the sample only, Ivaldi and McCullough restrict their findings to pure technological effects of separation. Neither the effects of transaction costs, in an integrated compared to a separated system, nor the effects of competition have been assessed. Additionally, like Bitzan, they consider different rail system characteristics in other countries and hence restrict their findings to the US rail freight system.

Cantos-Sanchez (2001) estimates a translog cost function from a panel of 12 European state-owned railways for the period 1973-90. His findings report cost substitutability between track infrastructure and passenger operations but cost complementarity between track infrastructure and freight operations. That is, higher track costs lead to lower passenger operation costs as well as higher freight operation costs. This result gives an indication for diseconomies of scope between passenger and freight operations. However, considering the risk that separated firms do not account for these interdependencies, this finding also gives reason to assume that there are benefits of vertical integration, as Nash and Rivera-Trujillo (2004) state.

A recent study on European railways by Friebel, Ivaldi and Vibes (2004) investigates the impact of policy reforms on 12 European national railway firms. By applying a production frontier model they compare passenger traffic efficiency for the period 1980-00, in which most of the European railway markets were reformed. They find that the implementation of reforms gradually improves efficiency whereas multiple reforms implemented simultaneously only have at best neutral effects. Controlling for the effect of separation Friebel et al. show that there are no significant differences in efficiency between fully integrated companies and organizationally separated firms, but that full institutional separation has a positive effect on efficiency. However, this analysis only holds when the United Kingdom is excluded from the dataset. Furthermore, the results

indicate that – in general – smaller railway firms (firm size being measured in terms of network length) have improved efficiency more than firms of larger size.

Overall, previous research on the economics of vertical integration in railways shows that the impact of scope economies on the efficiency of railway systems is still ambiguous. Aside from that, several important issues, such as different production technologies in integrated and separated organisational arrangements and limitations due to specific behavioural assumptions, have not been addressed so far. Therefore, in order to estimate scope economies in technological and especially transactional sense we apply data envelopment analysis (DEA). Our pan-European data set incorporates railway firms from 27 European countries for the period 2000-04. In contrast to pervious studies the data includes not only integrated railway firms, but separated firms, differentiated between infrastructure managers, passenger operators and freight operators. To our knowledge, this is the first study using this kind of data in a European railway efficiency comparison. Furthermore, considering the estimation technique we compare two different production frontiers of separated and integrated firms rather than analysing one frontier derived from all firms, as done in most previous work. Thus we explicitly incorporate different production technologies. Several variations of this technique can be found in Ferrier et al. (1993), Prior (1996), Fried, Schmidt and Yaisawarng (1998), Prior and Sola (2000), Kittelsen and Magnussen (2003) and Cummins, Weiss and Zi (2003), evaluating scope and diversification economies in the banking, hospital, health care and insurance sector.

3 Methodology

To specify a multiple-output multiple-input production technology we apply the distance function approach proposed by Shephard (1953, 1970). Compared to other representations of technologies, such as cost or revenue functions, it requires no specific behavioural objectives such as cost minimisation or profit maximisation, which are likely to be violated in the case of partly state-owned and highly regulated industries as European railways (Coelli and Perelman, 2000).

Distance functions can be differentiated into input-oriented and output-oriented distance functions. The input orientation assumes that the output set is determined by exogenous factors and hence that the influence of firms on output quantities is limited; the output orientation assumes exactly the same for the input set. For railways, both versions can be appropriate. Supporting the input-orientated approach one could argue that the demand for outputs is influenced highly by macro-economic factors (e.g. customer density) as well as state-controlled public transport requirements. A major aspect in favour of an output-oriented approach is the existence of hardly controllable input factors, for example political influence on capital expenditures (Coelli and Perelman, 1999). But since we use a constant return to scale estimation approach where the input-oriented distance measure equals the output oriented distance measure in reciprocal terms, we limit our model to the input-orientation.[3]

Modelling a production technology as an input distance function one can investigate how much the input vector can be proportionally reduced holding the output vector fixed. Assuming that the technology satisfies the standard properties listed in Färe and Primont (1995) it can be defined as:

$$D_I(x, y) = \max\{\ \theta : (x/\theta) \in\ L(y)\}, \tag{3}$$

where the input set *L(y)* represents the set of all input vectors x that can produce the output vector y. The function is non-decreasing, positively linearly homogeneous and concave in x, and increasing in y (Lovell et al., 1994). From $x \in L(y)$ follows $D_I(x, y) \geq 1$. A value equal to unity identifies the respective firm as being fully efficient and located on the frontier of the input set. Values greater than unity belong to input sets within the frontier indicating inefficient firms.

In order to estimate the distance functions and obtain information about technical efficiency and scope economies of European railways we use data envelopment analysis (DEA), a method introduced by Charnes, Cooper and Rhodes (1978). DEA is a non-parametric approach which constructs a piece-wise linear production frontier enveloping all observed data points. This production frontier can be estimated either under constant returns to scale (CRS) or under variable returns to scale (VRS). We follow the CRS ap-

3 The output-oriented model is defined in a similar way (see for instance *Coelli and Perelman* 1999).

proach, assuming that the observed firms can alter their size and hence identify firms departing from optimal scale as inefficient.[4]

Taking it as given that the firms use K inputs and M outputs the CRS input-oriented frontier is calculated by solving the following linear optimization program for each of N firms:

$$\begin{aligned} &\max \ \theta, \\ &\text{s.t.} \quad -y_i + Y\lambda \geq 0, \\ &\qquad x_i/\theta - X\lambda \geq 0, \\ &\qquad\qquad \lambda \geq 0, \end{aligned} \tag{4}$$

where X is the $K \times N$ matrix of inputs and Y the $M \times N$ matrix of outputs. The i-th firm's input and output vectors are represented by x_i and y_i respectively. λ is a $N \times 1$ vector of constants and θ is the input distance measure. As defined earlier in this section this measure indicates a firm's technical (in)efficiency.[5]

To analyze economies of scope in the railway sector we calculate so called super-efficiency scores in a second step. Super-efficiency measures can be obtained by calculating the efficiency of one group of observations relative to a production technology defined by another, reference group of observations; i.e., we compare the efficiency of integrated railway firms relative to the efficiency frontier of non-integrated railway firms. In order to obtain a comparable set of non-integrated firms we follow a suggestion from Morita (2002) and construct virtually integrated firms from samples of different separated firms: assume, for example, that there are two kinds of products, A and B, which could be produced separately in two firms or jointly in one firm. There are n^A firms producing only A, n^B firms producing only B and n^{AB} firms producing both A and B. These firms can be compared by combining the n^A firms with the n^B firms receiving a number of $n^A \times n^B$ virtual firms. These virtual firms use the same inputs to produce the same outputs as the n^{AB} firms, but producing them under an alternative production technology.

For J integrated firms and S non-integrated firms, the input distance function for an integrated firm j relative to the non-integrated firms` frontier can be defined as:

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4 In contrast, the VRS approach compares firms within similar scale; assuming VRS is appropriate when due to exogenous determinants (e.g. regulatory framework and political influence) the firm size cannot be influenced by the management directly. Although this may still be the case in some European railway industries we argue that an efficiency comparison should consider the long-term economic perspective, including increasing European deregulation and integration, i.e., less country specific regulation and political influence.

5 Note that this is the Shepard measure of technical efficiency. The corresponding Farrell measure can be obtained by taking the reciprocal of the Shepard distance function (see for instance *Wilson* 2005).

$$D_S\left(x_j, y_j\right) = \max\{\theta : \left(x_j / \theta\right) \in L^S\left(y_j\right)\},\ j = 1, 2, \ldots, J \tag{5}$$

where $L^S(y_j)$ represents the set of all input vectors x of the non-integrated firms that can produce the output vector y_j. In contrast to a company's input distance function value calculated within its own group (which is greater or equal to unity), the relative efficiency value calculated to a reference set of the other companies' group can take values between zero and infinity.

The corresponding CRS super efficiency model is calculated by solving the following linear optimisation program J times for each of the integrated firms:

$$\begin{aligned} &\max \theta_j, \\ &\text{s.t.} \quad -y_j + Y_s\lambda_s \geq 0, \quad \text{j} = 1, 2, \ldots, \text{J} \\ &\qquad x_j / \theta_j - X_s\lambda_s \geq 0, \quad \text{s} = 1, 2, \ldots, \text{S} \\ &\qquad\qquad \lambda_s \geq 0, \end{aligned} \tag{6}$$

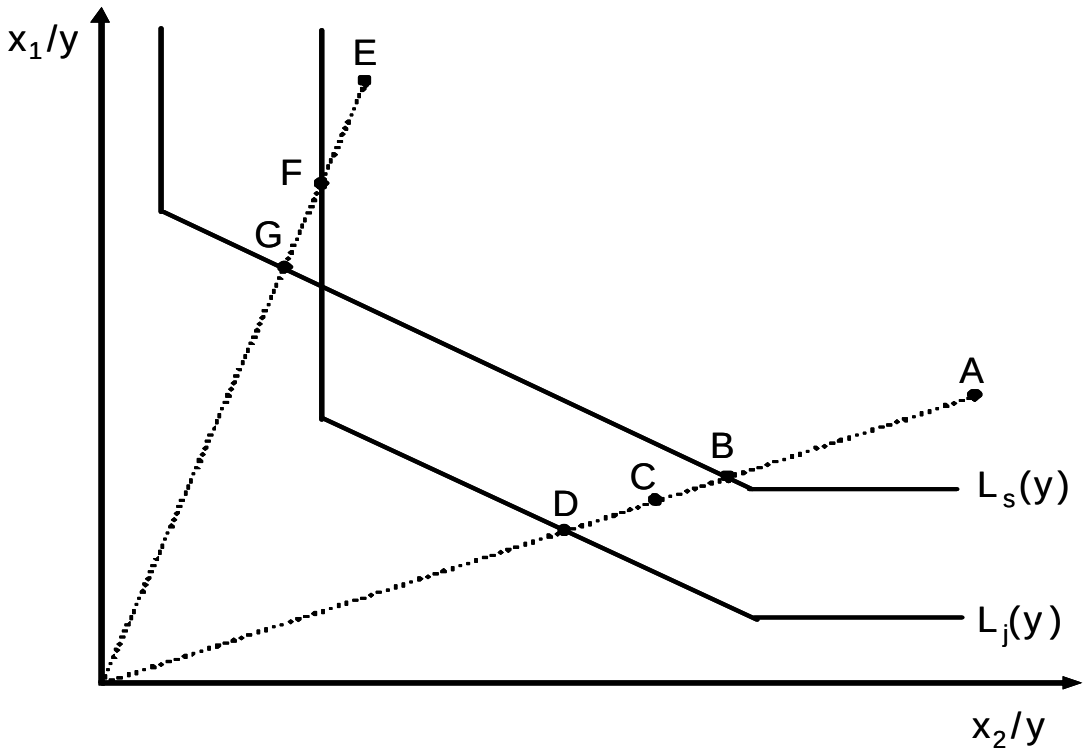
where X_s is the $K \times N$ input matrix and Y_s the $M \times N$ output matrix of all non-integrated firms; x_j is the input vector and y_j the output vector of the evaluated integrated firm, and λ_s is a $N \times 1$ vector of constants of the separated firms. If the input distance function value, i.e. the super efficiency score, for the evaluated firm θ_j is lower than unity the integrated firm is dominant to (more efficient than) the non-integrated frontier, whereas a value greater than unity indicates a dominance of the non-integrated firms` frontier to the evaluated firm. However, if for the integrated firm the input distance function value relative to its own group θ is also greater than unity, the firm is dominated by its own group's frontier also. Hence, considering the super efficiency scores only is not sufficient to identify the favourable technology or the existence of economies (diseconomies) of scope. Consequently, as suggested by Cummins, Weiss and Zi (2003) we measure the distance between the two production frontiers by calculating the ratio of the efficiency and super efficiency scores.

To illustrate this one can consider non-integrated and integrated firms producing a single output with two inputs. The two input production frontiers are shown in Figure 1 where the production frontier for the integrated firms is labelled $L_j(y)$, and the production frontier for non-integrated firms is labelled $L_s(y)$.[6] Firms being fully efficient operate on their respective frontier and hence show distance function (efficiency) values relative to their own group equalling unity. Economies (diseconomies) of scope, for all observations, can be identified if the production frontiers do not intersect and the inte-

6 Figure 1 and its description follow *Cummins, Weis and Zi* (2003)

grated (non-integrated) frontier places closer to the origin. If the two production frontiers exhibit an intersection point as shown in figure 1, economies of scope for some operating observations and diseconomies of scope for other operating observations can be identified.

Figure 1:
Economies and diseconomies of scope



For example, assume an integrated firm operating at point A in Figure 1. The distance function value relative to the integrated frontier is $\theta = 0A/0D > 1$ and the distance function value relative to the separated frontier, which is $\theta_j = 0A/0B > 1$ indicate this firm being dominated by its own and the other group's frontier. In order to measure which frontier places closer to the origin and hence to test if economies or diseconomies of scope occur for firm A, we calculate the ratio of the two distance function (efficiency) values:

$$\frac{\theta}{\theta_j} = \frac{0A/0D}{0A/0B} = \frac{0B}{0D} \tag{7}$$

Since the distance function value of point A relative to the integrated frontier is greater than its efficiency score, calculated with respect to the separated frontier, the ratio from formula 6 is greater than unity, indicating the integrated ('own') frontier places closer to

the origin. Hence, for this firm, economies of scope can be identified. The opposite case – diseconomies of scope – can be shown for an integrated firm operating at point E. While both distance function values – relative to its own frontier $\theta = 0E/0F$ and relative to the other group's frontier $\theta_j = 0E/0G$ – are greater than unity again, the ratio $\theta/\theta_j = 0G/0F$ is smaller than unity, since the separated frontier places closer to the origin than the integrated frontier. In summary, if the ratio is greater (lower) than unity a firm's own frontier dominates (is dominated by) the other group's frontier and if the ratio is lower than unity the own frontier is dominated by the other group's frontier for any production point. Hence, for integrated firms a ratio greater than unity indicates economies of scope and a ratio lower than unity indicates diseconomies of scope.

Since DEA efficiency measures are only point estimators calculated within a finite sample, they are highly sensitive to sampling variations and errors in the data, and lack common statistical properties. In order to overcome this shortcoming, we apply a bootstrap procedure. Bootstrapping, introduced by Efron (1979), is based on the idea that when the original observed sample mimics the underlying population, every random draw from this sample with replacement can be treated as a sample from the underlying population itself. It is used when the original sampling distribution of the estimator of interest, e.g. of the efficiency measures, is unknown. In general, the bootstrap of our efficiency estimates can be described as follows: We first compute the efficiency measure $\hat{\theta}_i$ for each firm by DEA from the observed sample. After that, we generate a b-th (b=1,2,…,B) bootstrap sample θ_b^* of size n with replacement from $\hat{\theta}_i$, i=1,…,n, and calculate the bootstrap estimate $\hat{\theta}_b^*$ by using DEA. This procedure is repeated B times to obtain a set of estimates $\hat{\theta}_b^*$, b=1,2…,B. Based on this sampling distribution the statistical properties of the estimated efficiency measures can be inferred.[7]

One major drawback of the outlined procedure is that it assumes a continuous true distribution F. However, especially in small samples with a large number of units identified as being fully efficient, the empirical distribution $\hat{F}$ of the efficiency scores is discontinuous with a positive probability mass at $\theta = 1$. Hence, $\hat{F}$ provides an inconsistent estimator of F (Cummins, Weiss and Zi, 2003). This problem can be solved with a smoothed bootstrap procedure, developed and extended by Simar and Wilson (1998, 2000), where the empirical distribution $\hat{F}$ is smoothed using a Gaussian kernel density estimator. In our analysis we use this bootstrap procedure to estimate the bias and variance of the DEA efficiency estimates, and to construct confidence intervals. As recommended by Hall (1986) we choose B=1000 bootstrap replications.[8]

7 For more details on the bootstrap see for instance *Efron* (1979) or *Efron and Tibshirani* (1993).

8 For details of the procedure, please refer to *Simar and Wilson* (1998, 2000).

4 Modelling approach and data description

The data set consists of 54 railway firms from 27 European countries throughout the period 2000-2004. Considering every year as an independent observation we receive a sample of 152 observations in total.[9] The data was mainly taken from the railway statistics published by the Union Internationale des Chemins de Fer (2004, 2005) and combined with information from the companies' annual reports and companies' statistics.

The firms are divided into four different groups: Integrated firms (IF), infrastructure managers (IM), passenger operators (PO) and freight operators (FO). Every group sells a different type of product, with the integrated firms offering all activities from a single source. The essential activity in railway operations is the infrastructure management which forms an indispensable requirement for transportation services. It is offered either by an infrastructure manager or an integrated firm and includes maintaining tracks, railway stations or signal facilities as well as schedule-monitoring and system-control. The infrastructure manager coordinates train movements, provides emergency service for defective transport devices and develops time tables. Recapitulating the infrastructure manager's tasks, he provides and sells network access and services to the transportation firms, subject to the condition of optimal capacity utilisation. We therefore use the variable *train-km driven on the network* as an output measure for infrastructure managers.[10] The second activity in railway operations is transportation, which can be distinguished between passenger and freight transportation. It is provided by passenger operators, freight operators or integrated firms. Since – for passenger operators – revenues depend on the number of passengers and the distance travelled, we use the variable *passenger-km* as an output measure. The freight operators' revenues depend on the amount and distance of tonnes transported. Hence, the corresponding output variable *freight tonne-km* is used.

Considering the input variables we specify two different models. While the first model (Model I) is based on physical measures for the input factors only, the second model (Model II) also takes a monetary figure into account. In the first model, *number of employees*, *number of rolling stock* and *net length* are used as physical measures for labor and capital input. In the second model, the 'physical' variables *number of employees* and *number of rolling stock* are substituted by the monetary variable *operating expenditure (OPEX)*. The variable represents the total operating expenses, including the costs of

9 The difference between 270 observations having full data coverage and the lower value of de facto 152 observations results from market entries later than 2000 and missing data mainly of 2004. Assuming every year as an independent observation includes effects of technical progress and catching-up in the efficiency scores. However, long asset live in relation to the rather short observed time period of five years suggests these effects as negligible (*Affuso, Angeriz and Politt*, 2002).

10 The data on train-kms driven on the network was published first for the year 2003 by the Union Internationale des Chemins de Fer (UIC). If available, the data for preceding years was taken from the annual reports. If not available, the train-km values of the biggest passenger and freight operators in the specific country where taken to approximate the value.

staff, materials, external charges, taxes, depreciation, value adjustments and provisions for contingencies. Although this variable already includes capital costs we still use the variable *net length* as a proxy for capital stock. We consider net length – as a long life asset – as a quasi-fixed input mainly built in the past and financed by capital grants from the government.[11] Furthermore it reflects the cost impact of differences in network structure and density (Smith, 2004).

Both models have advantages and disadvantages. The usage of physical measures for international comparison neglects the differences in relative factor prices among the countries; on the other hand, using monetary values raises the problem of differences in price levels, accounting rules and currency conversion. To limit this problem we follow Jamasb and Pollitt (2003) by converting the financial data of operating costs into one monetary unit, the euro. By applying purchasing power parities provided by Eurostat (Eurostat, 2004) instead of conventional exchange rates, we account not only for currency conversion but also for differences in price levels and purchasing power among the countries. Nevertheless, the problem of varying accounting standards among the countries remains. We estimate both models and check for differences by comparing the results therefore.

Table 1 shows the firms sorted after their type of activity and the selected variables. While for integrated firms all described input and output variables are part of their corresponding production technology, the variable set for the non-integrated firms – passenger operators, freight operators and infrastructure managers – differ by their type of activity. In order to estimate economies of scope we use the parameter values of non-integrated firms to construct virtually integrated firms, which are comparable to the really integrated firms: every infrastructure manager is combined with every passenger and every freight operator by accumulating their individual parameter values. A new group of virtually integrated firms (VF) is generated, using a comparable production technology, since those VF share the same inputs and produce the same outputs as ‘real’ integrated firms.

11 This approach has been used quite frequently in previous literature, see *Cantos, Pastor and Serrano* (2002) for a short review.

Table 1:
Variables sorted by type of activity and model specification

	Input variables				Output variables		
Type of activity	No. of employees	No. of Rolling stock	Total costs	Net length	Train-km	Pass.-km	Tonne-km
IF	√	√	√	√	√	√	√
IM	√		√	√	√		
PO	√	√	√			√	
FO	√	√	√				√
VF	√	√	√	√	√	√	√

Tables 2 and 3 show the summary statistics of the data used in the each model, classified for 'real' integrated and 'virtually' integrated firms. The number of observations of 'real' integrated firms differs slightly between the estimated models – 75 observations for Model I and 73 observations for Model II – due to missing data. The observations of 'virtually' integrated firms in Model I are generated by combining 33 observations of infrastructure managers with 16 observations of passenger operators and 11 observations of freight operators. In total, we obtain a number of 5808 'virtually' integrated firms for this model. For Model II, 23 observations of infrastructure managers, 27 observations of passenger operators and 8 observations of freight observations are combined to a total number of 4968 'virtually' integrated firms. Again, the difference in the numbers is due to missing data. To eliminate extreme virtual input-output combinations, we adjust the sub-sample of 'virtually' integrated firms for outliers by applying the method suggested by Hadi (1992, 1994), which identifies multiple outliers in multivariate data. For Model I, 2508 observations were dropped, leaving 3330 observations of 'virtual' integrated firms. Data for Model II is adjusted for 2160 outliers, leaving 2808 observations of 'virtual' integrated firms in total.[12]

12 This large number of outliers identified, results from a high fraction of 'unrealistic' virtual input/output combinations, combinations of very large infrastructure managers with small passenger operators for instance.

Table 2:
Model I – Summary statistics

	'Real' integrated firms			'Virtually' integrated firms		
	Mean	Max	Min	Mean	Max	Min
No. of employees	50517	249251	952	12870	36192	3465
No. of rolling stock	40351	219574	223	4981	11893	747
Network length (in km)	7331	36588	180	4665	9882	2047
Passenger-km (in millions)	11494	74459	126	4653	6621	2204
Tonne-km (in millions)	14258	76815	14	4952	13120	107
Train-km (in thousands)	134764	988200	2382	63158	128000	22667
No. of observations	75			3300		

Table 3:
Model II – Summary statistics

	'Real' integrated firms			'Virtually' integrated firms		
	Mean	Max	Min	Mean	Max	Min
OPEX (in millions of €)	3281	29669	79	1439	3927	329
Network length (in km)	7474	36588	180	4055	5854	2273
Passenger-km (in millions)	11779	74459	126	4795	14666	7
Tonne-km (in millions)	14400	76815	14	5854	13120	456
Train-km (in thousands)	137999	988200	2382	45151	64341	36442
No. of observations	73			2808		

5 Results

In this section, we present the results of the estimated models. First, we analyse the technical efficiency results obtained by the DEA bootstrap procedure. We then extend the discussion to the evaluation of contingent economies of scope.

Analysing the DEA bootstrap estimation results (Table 4), the following conclusions can be drawn. For both models, the bias-corrected distance function values are greater than the original efficiency scores on average, indicating that a standard DEA approach without a bootstrap procedure tends to overestimate efficiency in our sample. For Model I (Model II) the average distance function value for the 'real' integrated firms is corrected by about 14% (6 percent) and the average efficiency value for the 'virtually' integrated firms by about 2 percent (1 percent), suggesting that bias-correction especially in small – data sensitive – samples is essential for correct efficiency results.

Table 4:
Summary statistics of original and bias-corrected distance function (efficiency) results[13]

Model I				
	'Real' integrated firms		'Virtual' integrated firms	
	Original	Bias corrected	Original	Bias corrected
Mean				
Efficiency	1.8378	2.0924	1.3786	1.4008
Standard deviation	0.7980	0.8837	0.3510	0.3552
Minimum efficiency	3.9459	4.5140	2.5344	2.6080
Maximum efficiency	1.0000	1.1597	1.0000	1.0024
Model II				
	'Real' integrated firms		'Virtual' integrated firms	
	Original	Bias corrected	Original	Bias corrected
Mean				
Efficiency	1.3466	1.4324	1.5202	1.5401
Standard deviation	0.3975	0.4116	0.3878	0.3924
Minimum efficiency	3.3012	3.4616	3.3123	3.4603
Maximum efficiency	1.0000	1.0728	1.0000	1.0017

13 All estimations are made with FEAR: A package for frontier efficiency analysis with R (*Wilson* 2005).

For Model I, the estimated bias-corrected distance function value of 2.0924 for the 'real' integrated firms implies that, on average, the same output quantity could have been produced despite of reducing the input usage by more than 52 percent. However, the high standard deviation of 0.8837 shows that the mean distance function value includes numerous extreme values. Comparing these results with Model II, where a monetary value *OPEX* is used instead of the physical variables *number of employees* and *number of rolling stock* shows a lower standard deviation (0.4115) as well as a much lower bias-corrected distance function value (1.4324), indicating a possible input reduction of about 30 percent on average. This suggests that the already addressed problem of physical measures – neglecting differences in relative factor prices among countries – has an influence on our Model I estimation results.[14]

Table 5 shows the bias-corrected distance function results for the 'real' integrated firms in Model I. Both distance values – in respect to their own frontier (2.0924) and to the separated frontier (2.0961) – indicate a high level of inefficiency, suggesting a possible reduction of 52 percent in inputs, on average, to reach either one of the efficiency frontiers. The average ratio of the distance function values slightly greater than unity (1.1109) suggest that the two frontiers place very close to each other, and that, on average, economies of scope can be assumed. However, since individually economies (diseconomies) of scope may vary widely due to variation in the in- and output mix, a judgement on just the average parameter values could be misleading. Nevertheless, separating the firms into two groups – with an individual ratio of the distance function values greater unity indicating economies of scope and below unity indicating diseconomies of scope – identifies scope for 42 and diseconomies of scope for 33 observations. This equals to 56 percent and 44 percent of all observations, respectively.

For Model II (Table 6), the estimated distance function value in respect to the 'virtually' integrated frontier (1.1932) indicates that, on average, a 'real' integrated firm needs an input reduction of about 16 percent to reach the efficiency frontier of the 'virtually' integrated firms. Compared to Model I, the standard deviation is reduced by more than 50 percent, again indicating less extreme values in this model. The average distance functions value ratio (1.4401) is greater than in Model I, implying increasing economies of scope when considering OPEX instead of the physical measures number of employees and rolling stock. Additionally, separating the sample into two groups – with regard to their individual ratio of the distance function values being greater or below unity – suggests that 51 observations (70 percent) show economies of scope and 22 observations

14 To control for structural differences among the countries, we estimated a truncated regression and regressed the efficiency scores of the real integrated companies upon GDP per capita, network density and population density. For the results of Model I, we found a significant and positive but very little influence of GDP per capita. For Model II, none of the variables had a significant influence on the efficiency scores.

(30 percent) diseconomies of scope. Hence, compared to Model I, a higher number of observations show economies of scope.

Table 5:
Bias-corrected distance function (efficiency) results - Model I

	'Real' integrated firms				
	θ	θ_J	θ / θ_J	Diseconomies of scope	Economies of scope
Mean	2.0924	2.0961	1.1109	0.8404	1.3236
Standard deviation	0.8837	1.0954	0.3195	0.1614	0.2422
Minimum	4.5140	4.8501	1.8848	0.9994	1.8848
Maximum	1.1597	0.6804	0.3686	0.3686	1.0076
No. of observations		75		33	42
		(100)		(44 percent)	(56 percent)

Table 6:
Bias-corrected distance function (efficiency) results - Model II

	'Real' integrated firms				
	θ	θ_J	θ / θ_J	Diseconomies of scope	Economies of scope
Mean	1.4324	1.1932	1.4401	0.8514	1.6940
Standard deviation	0.4116	0.4810	0.8252	0.0916	0.8711
Minimum	3.4616	2.6297	4.0851	0.9963	4.0851
Maximum	1.0728	0.2781	0.6007	0.6007	1.0170
No. of observations		73		22	51
		(100 percent)		(30 percent)	(70 percent)

6 Conclusions

Our analysis of a sample of 50 railway companies from 27 European countries observed over a period of five years from 2000 to 2004 provides a first pan-European distance function approach addressing economies of scope in railways and confirms the findings from the U.S. Within a model using physical measures only, we find slight efficiency advantages for integrated companies on average and observe economies of scope for a majority of observations. Including monetary figures, more precisely operating expenses, produces even more explicit results: in a second model, we show that integrated railway companies are on average relatively more efficient than virtually integrated companies, and find that a clear majority (70 percent) of the railway companies observed indicate economies of scope.

Despite these results, the policy implications are ambiguous; indeed, economies of scope exist for a majority of integrated European railway companies. Future sector restructuring should be aware of that issue and avoid increasing transaction costs unnecessarily. On the other hand, not disentangling the railway sector further retains discriminatory incentives and complicates regulation. Policy makers should carefully outweigh positive and negative aspects of vertical integration in railways.

Further research on economies of scope in the European railway industry should address dynamic aspects of market liberalisation and productivity development over time. Especially a company's regulatory environment and its experience might have a significant impact on relative efficiency. Also, aspects of railway safety and quality of service need to be incorporated in order to control for issues of particular importance, probably negatively correlated with a company's level of cost.

References

Affuso, L.; Angeriz, A.; Pollitt, M. G. (2002): Measuring the Efficiency of Britain's Privatised Train Operating Companies. London Business School, Regulation Initiative Discussion Paper Series, No. 48.

Baumol, W. J.; Panzar, J. C.; Willig, R. D. (1982): Contestable Markets and the Theory of Industrial Structure. Harcourt Brace Jovanovich, New York.

Bitzan, J. D. (2003): Railroad Costs and Competition: The Implications of Introducing Competition to Railroad Networks. Journal of Transport Economics and Policy, 37 (2), pp. 201-225.

Cantos, P.; Pastor, J.; Serrano, L. (1999): Productivity, Efficiency and Technical Change in the European Railways: A Non-parametric Approach. Transportation, 26 (4), pp. 337-357.

Cantos, P.; Maudos J. (2000): Efficiency, Technical Change and Productivity In The European Rail Sector: A Stochastic Frontier Approach. International Journal of Transport Economics, 27 (1), pp.55-76.

Cantos-Sanchez, P. (2001): Vertical relationships for the European railway industry. Transport Policy, 8 (2), pp. 77-83.

Cantos, P.; Pastor, J.; Serrano, L. (2002): Cost and revenue inefficiencies in the European railways, International Journal of Transport Economics, 29 (3), pp. 279-308.

Charnes, A.; Cooper, W.W.; Rhodes, E. (1978): Measuring the efficiency of decision making units. European Journal of Operational Research, 2 (6), pp. 429-44.

Coelli, T.; Perelman, S. (1999): A comparison of parametric and non-parametric distance functions: With application to European railways. European Journal of Operational Research, 117 (2), pp. 326-339.

Coelli, T.; Perelman, S. (2000): Technical Efficiency of European railways: a distance function approach. Applied Economics, 32, pp. 1967-1976.

Cummins, D. J.; Weiss, M. A.; Zi, H. (2003): Economies of Scope in Financial Services: A DEA Bootstrapping Analysis of the US Insurance Industry. The Wharton School, Philadelphia, PA. Unpublished Manuscript.

Efron, B. (1979): Bootstrap methods: another look at the jackknife. Annals of Statistics, 7, pp. 1-16.

Efron, B.; Tibshirani, R. J. (1993): An introduction to the Bootstrap. Chapman and Hall, New York.

Eurostat (2005), Purchasing power parities (PPP) and comparative price level indices for the ESA95 aggregates, http://epp.eurostat.cec.eu.int/portal/page?_pageid= 1073,46870091 &_ dad= portal &_schema=PORTAL&p_product_code=PPPSNA95, 19.09.2005.

Färe, R.; Primont, D. (1995): Multi-Output Production and Duality: Theory and Applications. Kluwer Academic Publishers, New York.

Ferrier, G. D.; Grosskopf, S.; Hayes, K. J.; Yaisawarng, S. (1993): Economies of diversification in the banking industry. Journal of Monetary Economics, 31, pp. 229-249.

Friebel, G.; Ivaldi, M.; Vibes, C. (2004): Railway (De)Regulation: A European Efficiency Comparison. CEPR Discussion Paper No. 4319, London, Centre for Economic Policy Research.

Fried, H. O.; Schmidt, S. S.; Yaisawarng, S. (1998): Productive, Scale and Scope Efficiencies in U.S. Hospital-Based Nursing Homes. INFOR, 36 (3), pp. 103-119.

Gathon, H. J.; Pestieau P. (1995): Decomposing Efficiency Into Its Managerial and Its Regulatory Components: The Case of European Railways. European Journal of Operational Research, 80, pp. 500-507.

Hadi, A. S. (1992): Identifying Multiple Outliers in Multivariate Data. Journal of the Royal Statistical Society, Series B, 54, pp. 761-771.

Hadi, A. S. (1994): A Modification of a Method for the Detection of Outliers in Multivariate Samples. Journal of the Royal Statistical Society, Series B, 56, pp. 393-396.

Hall, P. (1986): On the Number of Bootstrap Simulations Required to Construct a Confidence Interval. Annals of Statistics, 14, pp. 1453-1462.

Ivaldi, M.; McCullough, G. J. (2004): Subadditivity Tests for Network Separation with an Application to U.S. Railroads (May 2004). CEPR Discussion Paper No. 4392.

Jamasb, T.; Pollitt, M. (2003): International Benchmarking and Regulation: An Application to European Electricity Distributions Utilities. Energy Policy, 31, pp. 1609-1622.

Kittelsen, S.; Magnussen, J. (2003): Economies of Scope in Norwegian hospital production – A DEA analysis, Health Economics Research Programme. Working Paper 2003: 8, University of Oslo.

Knieps, G. (2004): Privatisation of network industries in Germany: a disaggregated approach. Discussion Paper Institut für Verkehrswissenschaft und Regionalpolitik, No. 100.

Lovell, C. A. K.; Richardson, S.; Travers, P.; Wood, L. L. (1994): Resources and functionings: a new view of inequality in Australia, in: W. Eichhorn (ed.), Models and Measurement of Welfare and Inequality. Springer Verlag, Berlin, pp. 787-807.

Morita, H. (2002): Analysis of economies of scope by data envelopment analysis: comparison of efficient frontiers. International Transactions in Operational Research, 10, pp. 393-402.

Mulder, M.; Lijesen, M.; Driessen, G. (2005): Vertical separation and competition in the Dutch rail industry – A cost-benefit analysis, paper submitted to the Third Conference on Railroad Industry Structure. Competition, and Investments, Stockholm, 21 and 22 October 2005.

Nash, C.; Rivera-Trujillo, C. (2004): Rail regulatory reform in Europe – principles and practice, paper presented at the STELLA Focus group 5 synthesis meeting. Athens, June.

Oum, T. H.; Yu, C. (1994): Economic Efficiency of Railways and Implications For Public Policy: A Comparative Study of The OECD Countries Railways. Journal of Transport Economics and Policy, 28 (2), pp. 121-138.

Prior, D. (1996): Technical efficiency and scope economies in hospitals. Applied Economics, 78, pp. 1295-1301.

Prior, D.; Sola, M. (2000): Technical Efficiency and economies of diversification in health care. Health Care Management Science, 3, pp. 299-307.

Shephard, R. W. (1953): Cost and Production Functions. Princeton University Press, Princeton.

Shephard, R. W. (1970), Theory of Cost and Production Function, Princeton University Press, Princeton.

Simar, L.; Wilson, P. W. (1998): Sensitivity analysis of efficiency scores: How to bootstrap in nonparametric frontier models. Management Science, 44, pp. 49-61.

Simar, L.; Wilson, P. W. (2000): Statistical inference in nonparametric frontier models: The state of the art. Journal of Productivity Analysis, 13, pp. 49-78.

Smith, A. S. J. (2006): Journal of Transport Economics and Policy, 40 (1), pp. 1-44.

Union Internationale des Chemins de Fer (2004): Railway times-series data 1970-2002. Paris.

Union Internationale des Chemins de Fer (2005b): International Railway Statistics 2003. Paris.

Williamson, O. (1975): Markets and hierarchies. The Free Press, New York.

Williamson, O. (1985): The Economic Institutions of Capitalism. The Free Press, New York.

Wilson, P. W. (2005): FEAR: A Package for Frontier Efficiency Analysis with R, unpublished working paper. Department of Economics, University of Texas at Austin, Austin, Texas.